Table 4 Interior Refinery Area (IRA)
Evaluation of Corrective Measures Alternatives

Alternative description: Monitored natural attenuation (MNA) utilizes naturally occurring physical, chemical, and/or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. This alternative typically requires groundwater monitoring to ensure compliance with site clean-up goals.

Remedial Decision: This is the proposed alternative for remediation of the IRA. To physically remediate groundwater of Montana Circular DEQ-7 Standards has been proven to be technically, physically, and financially infeasible. Investigations at the Refinery have led to the assumption that dissolved-phase plumes in the IRA are contained and being remediated at the Refinery by natural attenuation processes. A monitoring plan will be required to evaluate natural attenuation parameters and will continue until Montana Circular DEQ-7 Standards have been met. A more detailed evaluation of the proposed remedies can be found in Section VI of the Statement of Basis.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Monitored Natural Attenuation with Institutional Controls	Utilizes engineered and natural processes to remediate free- and dissolved phase hydrocarbon. May require years to complete. Entire extent of subsurface impacts would not be immediately addressed. Physical characteristics of the COC could potentially limit performance. Proper monitoring and sufficient groundwater chemistry is required.	Process occurs naturally and would have no O & M requirements. Long-term groundwater monitoring and sampling would be the only requirements to ensure natural attenuation is proceeding. Process has been used effectively at many sites.	Past monitoring events have indicated that natural attenuation is currently working to manage dissolved-phase constituents. Monitoring of the MNA process is already being performed.	Safety concerns would be minimal with the MNA alternative. Potential for exposure to organic vapors would exist during installation of any additional monitoring wells, and management of impacted soils soil to on-site construction workers. Contact with organic constituents would be a concern during groundwater monitoring.	MNA addresses dissolved-phase COC in the refinery interior. MNA presents no short- or long-term adverse effects to potentially sensitive areas or receptors. Short- and long-term beneficial effects include destruction of dissolved-phase hydrocarbons, and containment within the site boundaries.	MNA would reduce potential long-term exposures by remediating dissolved-phase constituents. Potential short- and long-term risks to site workers would exist during well construction and routine monitoring.	$973, 674

Note: COC means chemical of concern.
O and M means operation and maintenance.

Table 5 NAPL Accumulation Areas
Evaluation of Corrective Measures Alternatives

Alternative Description: NAPL Recovery from Engineered Wells is an alternative that would use existing and possibly new wells designed to allow recovery of non-aqueous phase liquid (NAPL) and groundwater. Each recovery well would be completed with a single-phase, total fluids, or dual-phase pumping system. Recovered fluids would be pumped to the existing refinery wastewater treatment system.

Remedy Decision: This alternative was rejected because, when compared with Vacuum-Enhanced NAPL Recovery, the remedial success was not as certain, there were many potential maintenance problems, and the cost of upgrading the water treatment facility was very high.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
NAPL Recovery from Engineered Wells	Varying degrees of effectiveness at many other sites. Limitations are high permeability of soils, recoverability of NAPL, potentially limited zone of influence, and potential of increased smearing.	System is reliable given the proper O & M. The frequency and complexity of the O & M requirements would be greater than the other alternatives. Potential maintenance issues include biofouling of the well screens, clogging of pump intake screens, pump failure, float switch adjustment, and waste water treatment system maintenance.	New wells are easily constructed. Placement of wells and associated piping could be limited by exisitng structures in process areas. Existing water treatment facility would have to be upgraded to facilitate an aggressive system of this type.	On-site workers would encounter common safety hazards during construction due to drilling equipment and construction activities. Buried and overhead utilities would have to be located and avoided during construction. Moderate risk while monitoring recovery and fluid levels.	Free-phase hydrocarbon mass would be reduced limiting the amount of NAPL available for dissolution and decreasing the total time to complete remediation. Potential migration of dissolved-phase constituents would be inhibited. No short- or long-term adverse effects to potentially sensitive areas.	Reduces potential short- and long-term exposures by removing free-phase and groundwater for treatment. Potential short- and long-term risks to site workers exist during construction and routine operation and maintenance.	$3,757,068

Table 5 (con't) **NAPL Accumulation Areas**
Evaluation of Corrective Measures Alternatives

Alternative Description: The vacuum-enhanced NAPL recovery alternative would utilize vacuum to influence hydrocarbon recovery from new and existing refinery wells. Fluid recovery would be accomplished using a mobile vacuum truck or centrally located vacuum unit.

Remedy Decision: **This is a proposed alternative for remediation of the NAPL Accumulation Areas.** This alternative was selected because of its proven effectiveness and demonstrated success, the aggressive nature of the remedy, and the reasonable cost. A more detailed evaluation of the proposed remedies can be found in Section VI of the Statement of Basis.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Vacuum Enhanced NAPL Recovery and Institutional Controls	Vacuum-enhanced recovery is effective at remediating existing NAPL plumes due to the high vacuum nature of the recovery technique. Utilizing the mobile vacuum truck unit would allow for intermittent recovery and recharge of NAPL to the recovery wells. Recovery method has proven to be effective at similar sites. Mobility and other physical characteristics of NAPL could limit performance. The alternative would not be affected by large fluctuations in the groundwater table.	The frequency and complexity of the O & M requirements would be less than the other alternatives due to the simple nature of the operation. Potential maintenance issues include biofouling of the well screens, vacuum truck breakdown, vacuum pump failure, and waste water treatment system maintenance. The vacuum-enhanced recovery alternative has demonstrated success and reliability in similar situations.	Using the mobile vacuum truck would require less than other alternatives considered. Evacuation could begin immediately at existing wells and be expanded to new recovery wells if necessary. Final remediation would potentially require less time to complete due to the more aggressive nature of this NAPL recovery method.	On-site workers would encounter common safety hazards during construction due to drilling equipment and construction activities. Buried and overhead utilities would have to be located and avoided during construction. Risk to nearby communities and environmental receptors would be negligible during construction or operation. Additional hazards (uneven terrain, explosive vapors, and moving equipment) would exist with operation of the mobile vacuum truck unit.	Remediates free-phase NAPL. No short- or long-term adverse effects to potentially sensitive areas. Impacted soil generated as part of new recovery well construction or piping installation would be properly managed to prevent contact with storm water or clean surface soil. Short- and long-term beneficial effects include recovery and treatment of NAPL and impacted groundwater.	Reduces potential short- and long-term exposures by removing free-phase and groundwater for treatment. Potential short- and long-term risks to site workers exist during construction of new recovery wells, and recovery efforts.	$2,612,216 (combined with all proposed alternatives for the NAPL Accumulation Areas)

Table 5 (con't) **NAPL Accumulation Areas**
Evaluation of Corrective Measures Alternatives

Alternative Description: Use of five total fluids recovery wells and two interceptor trenches to create a capture zone for NAPL recovery. Descriptions of these alternatives can be found in Section IV.1.b.vi. and IV.1.b.vii. of this document.

Remedy Decision: **This is a proposed alternative for remediation of the NAPL Accumulation Areas.** This alternative was selected because of its proven effectiveness and demonstrated success, reasonable cost, and immediate protection of the potential of NAPL releasing to the Yellowstone River. However, expansion of these remedial alternatives was evaluated and found to be impractical.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Use of Existing Five Total Fluids Recovery Wells and Two Interceptor Trenches	Creates a diversion of groundwater away from it's preferred path toward the river. The Interceptor Trenches would further remove the contaminant's ability to flow off site. Recovery method has proven to be effective at similar sites. Mobility and other physical characteristics of NAPL could limit performance.	Potential maintenance issues include pump failure. The use of fluids recovery wells and interceptor trenches has demonstrated success and reliability in similar situations.	This alternative is already being implemented at the site as an interim measure.	Risk to workers, nearby communities, and environmental receptors would be negligible during operation.	No short- or long-term adverse effects to potentially sensitive areas. Short- and long-term beneficial effects include recovery and treatment of NAPL and impacted groundwater.	Reduces potential short- and long-term exposures by removing free-phase and groundwater for treatment.	$2,612,216 (combined with all proposed alternatives for the NAPL Accumulation Areas)

Table 6 River Boundary Areas
Evaluation of Corrective Measures Alternatives

Alternative description: Air sparging would consist of installing specially designed wells to a depth several feet below the historical water table elevation. Atmospheric air would be injected through the wells to increase the dissolved oxygen concentration to the passing groundwater and strip volatile hydrocarbon compounds. As hydrocarbon-degrading bacteria utilize oxygen as an energy source, air sparging would enhance subsurface conditions for biodegradation.

Remedy Decision: This is one of the proposed remedial alternatives for the River Boundary Areas. This alternative was selected because of its proven effectiveness at the Refinery through interim measures, because of the active treatment nature of the method, and because of the negligible risk to human health and the environment during operations. A more detailed evaluation of the proposed remedies can be found in Section VI of the Statement of Basis.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Air Sparging	Addresses dissolved-phase constituents through volatilization and bioremediation. Limited by high hydraulic conductivity and geologic heterogeneities. Method has been tested at the refinery with positive results. Final remediation of the dissolved-phase plumes would potentially require less time to complete due to the active treatment nature of the method.	Multiple O & M requirements including: compressor maintenance, manifold maintenance and repairs, piping repairs, and well screen cleaning. Potential for fouling problems.	New well and piping installation may be hindered by utilities and other structures. Electrical power would need to be installed to power the air compressor system. Piping may need to be routed underground.	On-site workers would encounter common safety hazards during construction due to drilling equipment and construction activities. Risk to nearby communities and environmental receptors would be negligible during construction or operation.	Remediates dissolved-phase COC present near the refinery river boundaries. No long-term adverse effects to potentially sensitive areas. Impacted soil generated would be properly managed to prevent contact with storm water or clean surface soil. Short- and long-term beneficial effects include treatment of dissolved hydrocarbon plumes to prevent further migration.	Reduces potential short- and long-term exposures by mass destruction of COC. Potential short- and long-term risks to site workers exist during construction and routine O & M. Hazards can be mitigated with proper use of PPE and engineering controls.	$1,095,742

Table 6 (con't) **River Boundary Areas**
Evaluation of Corrective Measures Alternatives

Alternative description: Phytoremediation would consist of planted vegetation along the river boundary to remediate dissolved-phase constituents and perform limited hydraulic control. Phytoremediation would include the direct use of living plants for in-situ remediation of impacted groundwater and soil through contaminant removal, degradation, or containment. Additionally, plant water uptake would act as nominal hydraulic control.

Remedy Decision: This is one of the proposed remedial alternatives for the River Boundary Areas. This alternative was selected because it has been proven effective, it provides a long-term option, and it has negligible effect on human health or the environment during remediation. A more detailed evaluation of the proposed remedies can be found in Section VI of the Statement of Basis.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Phytoremediation	Has been proven effective at other sites provided the method limitations are not exceeded. Conditions at the site are conducive to its effective use. A long-term option that would not produce immediate results.	Reliability depends on long-term maintenance of planted trees and favorable climatic conditions.	Planting of trees in sufficient quantity and density depends on availability of space, existing pavement and structures.	For phytoremediation the only safety concerns would be heavy equipment usage during planting of grown trees.	Phytoremediation would contribute to the destruction of dissolve-phase COC, reducing the mass of COC that could potentially migrate off-site.	Long-term option that would not produce immediate results. Once the plants and root systems were established results may become apparent. Impacted soil might be contacted during planting. Long-term effects would be to reduce exposure to receptors.	$743,706

Table 6 (con't) **River Boundary Areas**
Evaluation of Corrective Measures Alternatives

Alternative description: Monitored natural attenuation (MNA) utilizes naturally occurring physical, chemical, and/or biological processes that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. This alternative requires groundwater monitoring to ensure compliance with site clean-up goals and to ensure the natural attenuation is working.

Remedial Decision: This is one of the proposed remedial alternatives for the River Boundary Areas. MNA is a recommended alternative to supplement other corrective measure alternatives for the River Boundary Areas. Investigations at the Refinery have provided evidence that natural attenuation is occurring and effectively controlling the extent of dissolved-phase plumes at most of the Site boundary. A monitoring plan will be required to evaluate natural attenuation parameters and will continue until Montana Circular DEQ-7 Standards have been met. A more detailed evaluation of the proposed remedies can be found in Section VI of the Statement of Basis.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Monitored natural attenuation	Utilizes engineered and natural processes to remediate free- and dissolved phase hydrocarbon. May require years to complete. Entire extent of subsurface impacts would not be immediately addressed. Physical characteristics of the COC could potentially limit performance. Proper monitoring and sufficient groundwater chemistry is required.	Process occurs naturally and would have no O & M requirements. Long-term groundwater monitoring and sampling would be the only requirements to ensure natural attenuation is proceeding. Process has been used effectively at many sites.	Past monitoring events have indicated that natural attenuation is currently working to manage dissolved-phase constituents. Monitoring of the NA process is already being performed. Would continue in conjunction with other corrective measures.	Safety concerns would be minimal with the MNA alternative. Potential for exposure to organic vapors would exist during installation of any additional monitoring wells, and management of impacted soils soil to on-site construction workers. Contact with organic constituents would be a concern during groundwater monitoring.	MNA addresses dissolved-phase COC at the river boundary. MNA presents no short- or long-term adverse effects to potentially sensitive areas or receptors. Short- and long-term beneficial effects include destruction of dissolved-phase hydrocarbons, and containment within the site boundaries.	MNA would reduce potential long-term exposures by remediating dissolved-phase constituents. Potential short- and long-term risks to site workers would exist during well construction and routine monitoring.	$509,958

Table 6 (con't) **River Boundary Areas**
Evaluation of Corrective Measures Alternatives

Alternative description: An engineered barrier wall would consist of a slurry wall or sheet pile wall constructed from the ground surface to bedrock. The barrier wall would physically contain the COC present near the river boundaries to prevent migration. Groundwater extraction wells would be installed to control the groundwater gradient near the barrier.

Remedial Decision: This alternative was rejected because of the following reasons: 1) Barriers walls would create groundwater mounding behind the walls, thus creating groundwater diversion issues and potentially mobilizing NAPL toward the river boundary, 2) Constructability is limited by the steep banks of the river boundary, 3) The concentrations of contaminants are low enough that they do not pose a risk which warrants such an extreme remedial measure; 4) More cost effective and implementable alternatives are available, and 5) a barrier wall diverts groundwater, but does not effectively remediate the groundwater.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Engineered barrier with hydraulic control	May prevent migration of dissolved-phase plumes toward the river boundaries. Would create groundwater mounding behind the barrier and additional flow around the barrier, requiring significant pumping for hydraulic control. Pumping would continue indefinitely, at least many decades.	Barriers are reliable provided tie-in to bedrock is good and hydraulic control is sufficient to prevent migration around the barrier.	Construction may be difficult due to geologic materials, the ability to create a good seal at the bedrock, existing structures, and slope stability issues near steep riverbanks. The large volumes of groundwater to be managed would require a new waste water treatment facility to be constructed.	On-site workers would encounter common safety hazards during construction of the engineered barrier wall due to heavy equipment and construction activities. Buried and overhead utilities would have to be located and avoided during construction. Risk to nearby communities and environmental receptors would be minimal during construction or operation. Slope stability near the riverbanks could be a serious safety hazard.	Physically contains and prevents migration of dissolved-phase COC. Groundwater extraction for gradient control would also provide remediation of dissolved-phase constituents.	Reduces potential short- and long-term exposures by physically containing dissolved-phase constituents. Potential short- and long-term risks to site workers during construction and routine O & M. Additional hazards would include contact with impacted soil during excavation and wall construction.	$7,371,000

Table 6 (con't) **River Boundary Areas**
Evaluation of Corrective Measures Alternatives

Alternative description: An engineered treatment barrier consists of an engineered barrier wall, such as a sheet-pile or slurry wall, with an exit "gate" containing a permeable reactive material or air sparging system to create a zone where biodegradation or other form of degradation occurs. The engineered treatment barrier would physically contain the river boundary plumes but allow groundwater to migrate through the treatment zone for remediation. The wall would extend from the ground surface to the site confining layer.

Remedial Decision: This alternative was rejected because the high groundwater flow velocities created by the system through the treatment zone would limit the retention time of affected groundwater. Without sufficient retention time the biologically driven reactions may not be sufficiently effective in hydrocarbon mass reduction.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Engineered treatment barrier	A suitable reactive material is not presently available. A reactive zone using air sparging may be limited by high groundwater flows created by constriction of flow paths. The higher flows may decrease retention time within the gate portion of the system to the extent that air sparging would not be sufficiently effective.	Extended down-time of the system would result in potential discharge of COC to the river. Tie-in of barrier wall portion to bedrock could be problematic and would be an important factor in system ability to meet objectives. Dependant on ability to prevent fouling within the gate to maintain free flow.	Construction may be difficult due to geologic materials, the ability to create a good seal at the bedrock, existing structures, and slope stability issues near steep riverbanks.	On-site workers would encounter common safety hazards during construction due to heavy equipment and construction activities. Risk to nearby communities and environmental receptors would be minimal during construction or operation. Slope stability near the riverbanks could be a serious safety hazard.	Could eliminate discharge of, and treat, dissolved-phase COC near river boundaries. Presents no long-term adverse to potentially sensitive areas.	Reduces potential short- and long-term exposures by physically containing dissolved-phase constituents. Potential short- and long-term risks to site workers during construction and routine O & M. Additional hazards would include contact with impacted soil during excavation and wall construction.	$785,000

Table 6 (con't) **River Boundary Areas**
Evaluation of Corrective Measures Alternatives

Alternative description: A hydraulic control system would consist of a series of groundwater pumping wells constructed along the river boundaries of the refinery. The groundwater pumping system would physically control the hydraulic gradient and help manage COC present near the river boundaries to prevent migration off-site.

Remedial Decision: This remedial alternative was rejected because controlling hydraulic gradients around the entire site river boundary would result in very large quantities of groundwater requiring treatment and would far exceed the capacity of water treatment facilities at the Site. Also, based on the geologic conditions in the subsurface, there are preferential pathways in which hydraulic control around the entire river boundary is not warranted.

	Technical						
Evaluated Alternative	**Performance**	**Reliability**	**Implementability**	**Safety**	**Environmental**	**Human Health**	**Cost**
Hydraulic control	Manages migration of dissolved-phase plumes toward the river boundaries by controlling the hydraulic gradient. Proven alternative at sites where hydrogeological conditions inhibit remediation by other methods.	Reliable assuming proper O & M of the pumps and wells.	Materials for pumping system construction are readily available. Construction of new waste water treatment facility would be necessary to manage the significant additional water flow.	On-site workers would encounter common safety hazards during construction due to drilling equipment and other heavy equipment and construction activities. Risk to nearby communities and environmental receptors would be minimal during construction or operation.	Manages the hydraulic gradient and migration of dissolved-phase COC. Presents no long-term adverse effects to potentially sensitive areas.	Reduces potential short- and long-term exposures by physically containing dissolved-phase constituents. Potential short- and long-term risks to site workers during construction and routine O & M.	$4,120,000